Summary of Play Types

JICARILLA APACHE INDIAN RESERVATION, NEW MEXICO

Reservation: Jicarilla Apache
Geologic Province: San Juan Basin (022)
Province Area: Approximately 8,000 sq miles (basin only)
Reservation Area: Approximately 1,000,000 acres

Total Production

Oil: San Juan Basin Cumulative Totals >240,000,000 BO
Gas: >18,000,000,000 CFG
NGL: Included
(figures from NMOGA, 1997 & FCGS, 1983)

Undiscovered resources and numbers of fields are for Province-wide plays. No attempt has been made to estimate number of undiscovered fields within the Jicarilla Apache Indian Basin

Play Type	USGS Designation	Description of Play	Oil or Gas	Known Accumulations	Undiscovered Resource (MMBOE) Field Size (> 1 MMBOE) min, median, mean	Play Probability (chance of success)	Drilling depths	Favorable factors	Unfavorable factors
1 Entrada Sandstone	2204	Associated with relict dune topography, sealed by anhydrite in overlying Todilto limestone	Oil	4,360 MBO (1995)	21.3 MMBO (mean)	1.0	5,000-6,000 ft.	1) produces south of reservation 2) excellent porosity and permeability 3) trend in southeast part of the basin untreated 4) reservation location favorable structurally	1) no Entrada production on reservation at present 2) sand rapidly looses perm-eablity below 9,000 feet 3) requires favorable paleo-topographic relief 4) must lie within depositional area of overlying Todilto
2 Basin Margin Dakota Oil	2206	Marine transgressive sand and non-marine channel sand structural and stratigraphic play, becoming more marine to the southeast.	Both	22.9 MMBO 62.1 BCFG	30.5 MMBO 91.6 BCFG associated 29.6 BCFG non-associated (mean)	1.0	1,000-3,000 ft.	1) multiple plays 2) natural fractures enhance low permeability 3) relatively shallow drilling to basin margin oil play 4) close market	1) stratigraphic traps 2) low matrix permeability 3) need fracture enhancement 4) comingled production
3 Tocito Gallup Sandstone Oil	2207	Oil and associated gas play in lenticular sandstone bodies of the Upper Cretaceous Gallup sandstone and Tocito sandstone lentil associated with Mancos Shale source rocks lying immediately above an unconformity.	Both	170 MMBO 200 BCFG	31.4 MMBO 62.9 BCFG associated 93.1 BCFG non-associated (mean)	1.0	1,100-6,800 ft.	1) possible multiple plays 2) high gas BTUs (1275) 3) relativly shallow on east 4) broad sand/reservoir distribution	1) stratigraphic traps 2) low volume recoveries 3) confusion in use of "Gallop" 4) little to no secondary recovery
4 Basin Margin Mesaverde Oil	2210	Confirmed stratigraphic oil play around margins of San Juan Basin. Can be structurally enhanced. Point Lookout sand intertounges with and sources from Mancos shale.	Oil	Unknown	7.8 MMBO 7.8 BCFG associated (mean)	0.80	1,000-3,000 ft.	1) possible multiple plays 2) high oil gravities 3) thick pay sections 4) ready market	1) future discoveries likely to be small 2) stratigraphic/hydrodynamic traps 3) low oil recoveries 4) drilled with natural gas
5 Fruitland-Kirkland Fluvial Sandstone Gas	2212	The play covers the central part of the basin and is characterized by gas prod-duction from stratigraphic traps in lenti-cular fluvial sandstone bodies enclosed in shale source rocks and (or) coal. The upper Cretaceous Fruitland formation and Kirkland shale are continental deposits and have a maximum combined thickness of more than 2,000 feet.	Gas	1.5 TCFG	261.1 TCFG	1.0	1,500-2,700 ft.	1) wide sand distribution in San Juan Basin 2) considered tight gas sands 3) high porosity 4) produces coal-bed methane from lower Fruitland	1) largest fields are already found 2) produces very little condensate 3) low permeability 4) produces from discontinous, lenticular channel sands

Conventional play type

Unconventional/Hypothetical play type

Table 1. Play summary chart.

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Play Type	USGS Designation	Description of Play	Oil or Gas	Known Accumulations	Undiscovered Resource (MMBOE) Field Size (> 1 MMBOE) min, median, mean	Play Probability (chance of success)	Drilling depths	Favorable factors	Unfavorable factors
6 Dakota Central Basin Gas	2205	Stratigraphic traps with coastal marine barrier bars and non-marine fluvial sands.	Gas	Unknown	8.2 TCFG (mean)	1.0	6,500-7,500 ft.	1) multiple plays 2) natural fractures enhance low permeability	1) strati graphic traps 2) low matrix permeability 3) need fracture enhancement 4) source rock quality variable
7 Mancos Fractured Shale	2208	Structural, monoclinical flexure, anticlinal nose, fractured shale play on San Juan margin.	Oil	30 MMBO total for basin 23.3 MMBO on reservation	188.9 MMBO 94.4 BCFG (mean)	1.0	1,400-7,500 ft.	1) shallow drilling depths 2) fracture enhanced permeability 3) nearby market 4) gravity drainage	1) new reserves will require directional drilling 2) requires pressure maintenance 3) small volume of gas produced is reinjected 4) must locate suitable fracture system
8 Central Basin Mesaverde Gas	2209	Comprises the Point Lookout and Cliffhouse members of the Mesaverde formation in sandstone buildups associated with strati graphic "benches." The thickness of this interval may be controlled to some extent by underlying structures oriented in a northwest direction. The Upper Mancos Shale intertongues with the basal Point Lookout Sandstone and has been positively correlated with oil produced from this interval (Ross 1980).	Gas		9.6 TCFG (mean)	1.0	4,000-5,300 ft.	1) possible multiple plays 2) high oil gravities 3) ready market 4) thick pay sections	1) future discoveries likely to be small 2) commonly drilled with natural gas 3) strati graphic/hydrodynamic traps 4) low oil recoveries
9 Pictured Cliffs Gas	2211	Gas production is from strati graphic traps in sandstone reservoirs enclosed in shale or coal at the top of the Upper Cretaceous Pictured Cliffs sandstone and is confirmed to the central part of the basin. Thicker shoreline sandstones produced by still sands, or brief reversals in the regression of the Cretaceous sea to the northeast have been most productive.	Gas	9 fields average 11 BCFG	3.3 TCFG (mean)	1.0	1,000-3,000 ft.	1) good porosities and permeabilities 2) ready market 3) high flow rates 4) higher than average BTU content (1175)	1) smectite/illite pore fill in deeper areas 2) strati graphic traps 3) non associated gas contains little condensate 4) highly variable thickness up to 400 feet

Table 2. Play summary chart (continued).

Conventional play type

Unconventional/Hypothetical play type

SUMMARY OF PLAY TYPES

The United States Geological Survey identifies several petroleum plays in the San Juan Basin Province and classifies them as Conventional and Unconventional. The discussions that follow are limited to those with direct significance for future petroleum development in the Jicarilla Apache Indian Reservation. Much of the following is extracted from USGS CD-ROM DDS-30, Release 2 (Gautier, et. al.,1995). Table 1 is a summary of USGS plays in the San Juan Basin.

DEFINITION OF A CONVENTIONAL PLAY

Discrete deposits, usually bounded by a downdip water contact, from which oil, gas, or NGL can be extracted using traditional development practices, including production at the surface from a well as a consequence of natural pressure within the subsurface reservoir, artificial lifting of oil from the reservoir to the surface where applicable, and the maintenance of reservoir pressure by means of water or gas injection.

ENTRADA PLAY

USGS 2204

The Entrada sandstone produces south and west of the Jicarilla Apache Indian Reservation. This discussion is included here because of the possibility that Entrada production may develop on the Reservation in the future.

The Entrada play is associated with relict dune topography on top of the eolian Middle Jurassic Entrada Sandstone in the southeastern part of the San Juan Basin and is based on the presence of organic-rich limestone source rocks and anhydrite in the overlying Todilto Limestone Member of the Wanakah Formation. North of the present producing area, in the deeper, northeastern part of the San Juan Basin, porosity in the Entrada decreases rapidly (Vincelette and Chittum. 1981). Compaction and silica cement make the Entrada very tight below a depth of 9,000 ft. No eolian sandstone buildups have been found south and west of the producing area.

Reservoirs: Some of the relict dunes are as thick as 100 ft but have flanks that dip only 2 degrees. Dune reservoirs are composed of fine-grained, well-sorted sandstone, massive or horizontally bedded in the upper part and thinly laminated, with steeply dipping crossbedding in the lower part. Porosity (23 percent average) and permeability (370 millidarcies average) are very good throughout. Average net pay in developed fields is 23 ft.

Source rocks: Limestone in the Todilto Limestone Member has been identified as the source of Entrada oil (Ross, 1980). There is a reported correlation between the presence of organic material in the Todilto Limestone and the presence of the overlying Todilto anhydrite (Vincelette and Chittum, 1981). This association limits the source rock potential of the Todilto to the deeper parts of the depositional basin in the eastern San Juan Basin. Elsewhere in the basin, the limestone was oxygenated during deposition and much of the organic material destroyed.

Timing and migration: Maximum depth of burial throughout most of the San Juan Basin occurred at this time. In the eastern part of the basin the Todilto entered the oil generation window during the Oligocene. Migration into Entrada reservoirs either locally or updip to the south probably occurred almost immediately; however, in some fields, remigration of the original accumulations has occurred subsequent to original emplacement.

Traps: All traps so far discovered in the Entrada Sandstone are stratigraphic and are sealed by the Todilto limestone and anhydrite. Local faulting and drape over deep-seated faults has enhanced, modified, or destroyed the potential closures of the Entrada sandstone ridges. Hydrodynamic tilting of oil-water contacts and for "base of movable oil" interfaces has had a destructive influence on the oil accumulations because the direction of tilt typically has an updip component. All fields developed to date have been at depths of 5,000 - 6,000 ft. Because of increase in cementation with depth, the maximum depth at which suitable reservoir quality can be found is approximately 9,000 ft.

Exploration status and resource potential: The initial Entrada discovery, the Media field (Figs. J-13, -14, -15), was made in 1953. Development was inhibited by problems of high water cut and high pour point of the oil, problems common to all subsequent Entrada field development. Between 1972 and 1977, seven fields similar to Media were discovered, primarily using seismic techniques. Areal sizes of fields range from 100 to 400 acres, and total estimated production of each varies from 150,000 BO to 2 MMBO. A number of areas of anomalously thick Entrada in the southeastern part of the San Juan Basin have yet to be tested, and there is a good probability that at least a few of these areas have adequate trapping conditions for undiscovered oil accumulations, but with similar development problems as the present fields. Limiting factors to the moderate future oil potential of the play include the presence of sufficient paleo topographic relief on top of the Entrada, local structural conditions, hydrodynamics, source-rock and oil migration history, and local porosity and permeability variations.

Analog Field
SOUTHWEST MEDIA ENTRADA

Figures J-13, J-14 and J-15

Location:	T19N, R3W, south of Reservation
Formation:	Entrada
Lithology:	Sandstone
Average Depth:	5,360 ft
Porosity:	23.8%
Permeability:	361 md
Oil/Gas Column:	30 feet
Average Net Pay Thickness:	30 feet
Estimated Ultimate Recovery:	1,800,000 BO
Other Information:	Oil gravity 33.5 degrees API, asphaltic base with high pour point. Reservoir is in structurally enhanced stratigraphic trap.

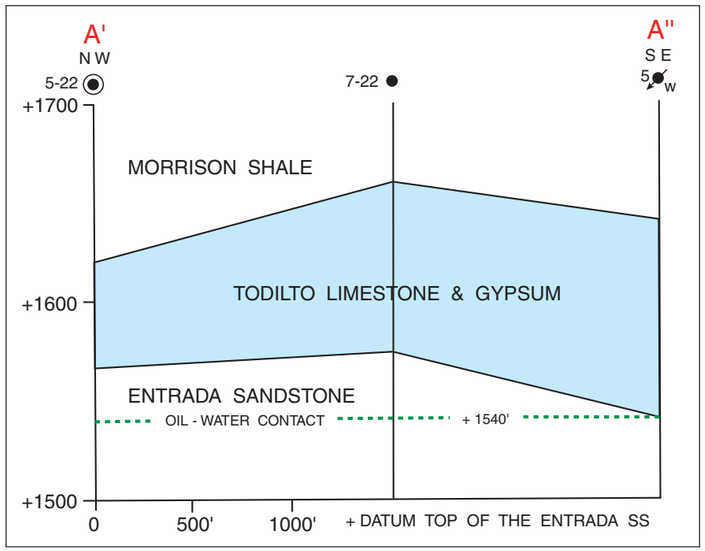

Figure J-13. Southwest Media Entrada Field section along A-A' - see Figure J-14 (after Reese, 1978).

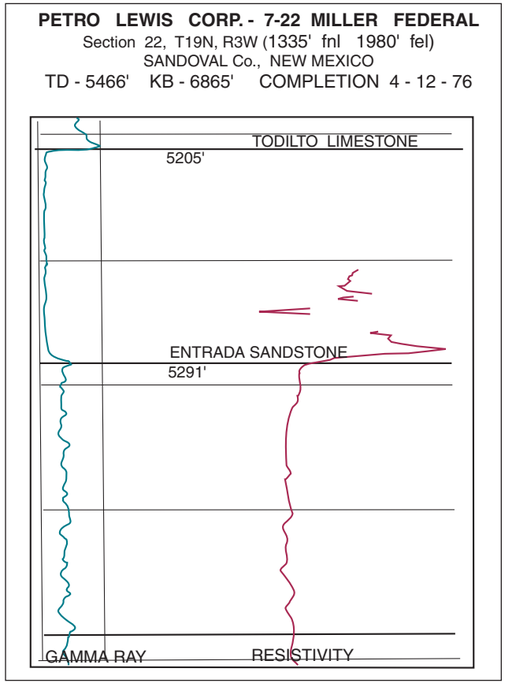

Figure J-15. Southwest Media Entrada Field example electric log (from Reese, 1978).

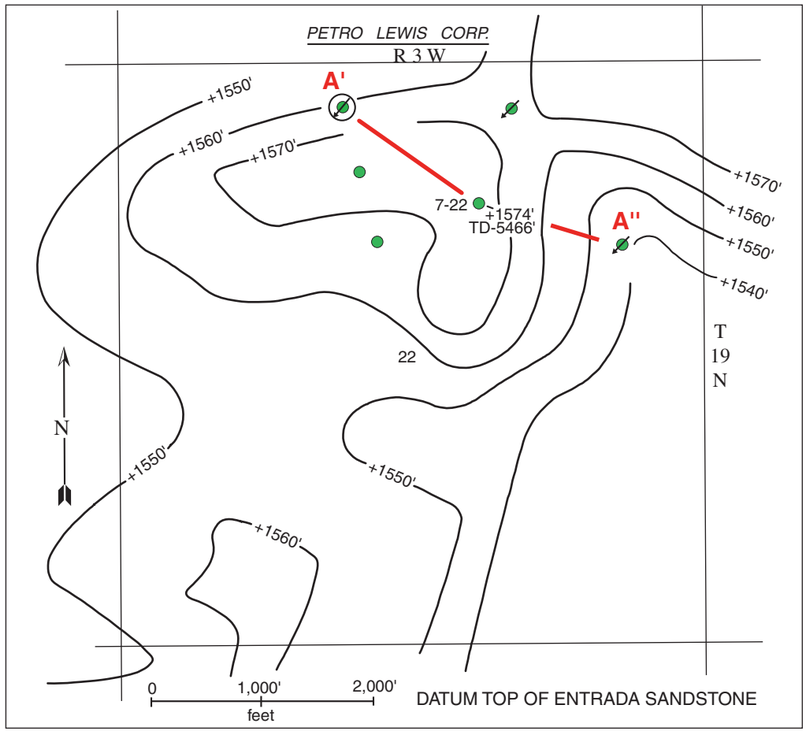

Figure J-14. Southwest Media Entrada Field. Structure contours on top of Entrada Sandstone. Figure J-13 is section along A-A' (from Reese, 1978).

Basin Margin Dakota Oil Play

USGS 2206

The Basin Margin Dakota Oil Play is both a structural and strati graphic play on the northern, southern, and western sides of the cen tral San Juan Basin. Because of the variability of depositional envi ronments in the transgressive Dakota Sandstone, it is difficult to characterize a typical reservoir geology. Most production has been from the upper marine part of the interval. but significant amounts of both oil and gas have also been produced from the nonmarine sec tion.

Reservoirs: The Late Cretaceous Dakota Sandstone varies from pre dominantly nonmarine channel deposits and interbedded coal and conglomerate in the northwest to predominantly shallow marine, commonly burrowed deposits in the southeast. Net pay thicknesses range from 10 to 100 ft; porosities are as high as 20 percent and per meabilities as high as 400 millidarcies.

Source rocks: Along the southern margin of the play, the Creta ceous marine Mancos Shale was the source of the Dakota oil. API gravities range from 44 degrees to 59 degrees. On the Four Corners platform to the west, nonmarine source rocks of the Menefee Forma tion were identified as the source (Ross, 1980). The stratigraphically higher Menefee is brought into close proximity with the Dakota across the Hogback Monocline.

Timing and oil migration: Depending on location, the Dakota Sand stone and lower Mancos Shale entered the oil window during the Oli gocene to Miocene. In the southern part of the area, migration was still taking place in the late Miocene or even more recently.

Traps: Fields range in size from 40 to 10,000 acres and most produc tion is from fields of 100 - 2,000 acres. Stratigraphic traps are typical ly formed by updip pinchouts of porous sandstone into shale or coal. Structural traps on faulted anticlines sealed by shale form some of the larger fields in the play. Oil production ranges in depth from 1,000 to 3,000 ft.

Exploration status and resource potential: The first discoveries in the Dakota play were made in the early 1920's on small anticlinal structures on the Four Corners platform. Approximately 30 percent of the oil fields have an estimated total production exceeding 1 MMBO, and the largest field (Price Gramps) has production of 7 MMBO. Future Dakota oil discoveries are likely as basin structure and Dakota depositional patterns are more fully understood.

Analog Field
LINDRITH GALLUP-DAKOTA SOUTH
Figures J-16 and J-17

Location:	T23-24N, R4W, on Reservation
Formation:	Dakota
Lithology:	Sandstone
Average	Depth: 7200 feet
Porosity:	12%
Permeability:	0.1 to 0.5 md, fracture enhanced
Oil/Gas Column:	200 feet
Average Net Pay Thickness:	40 feet
Other Information:	Estimated ultimate recovery 80,000 BO per well, comingled. Oil averages 43 degrees API and is a sweet crude.

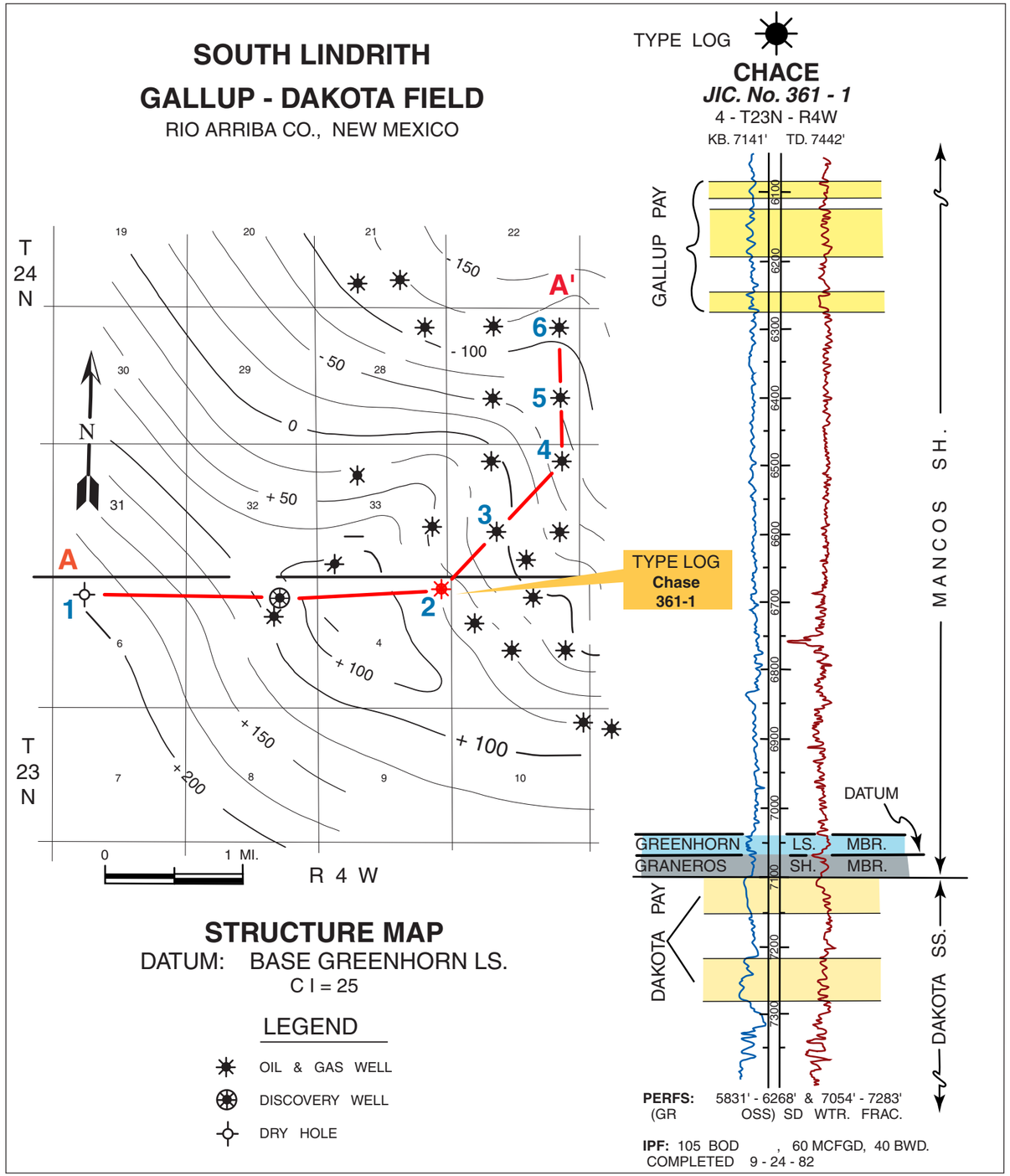

Figure J-16. South Lindrith Gallup-Dakota Field, structure map and example log (from Matheny, 1978, p. 982).

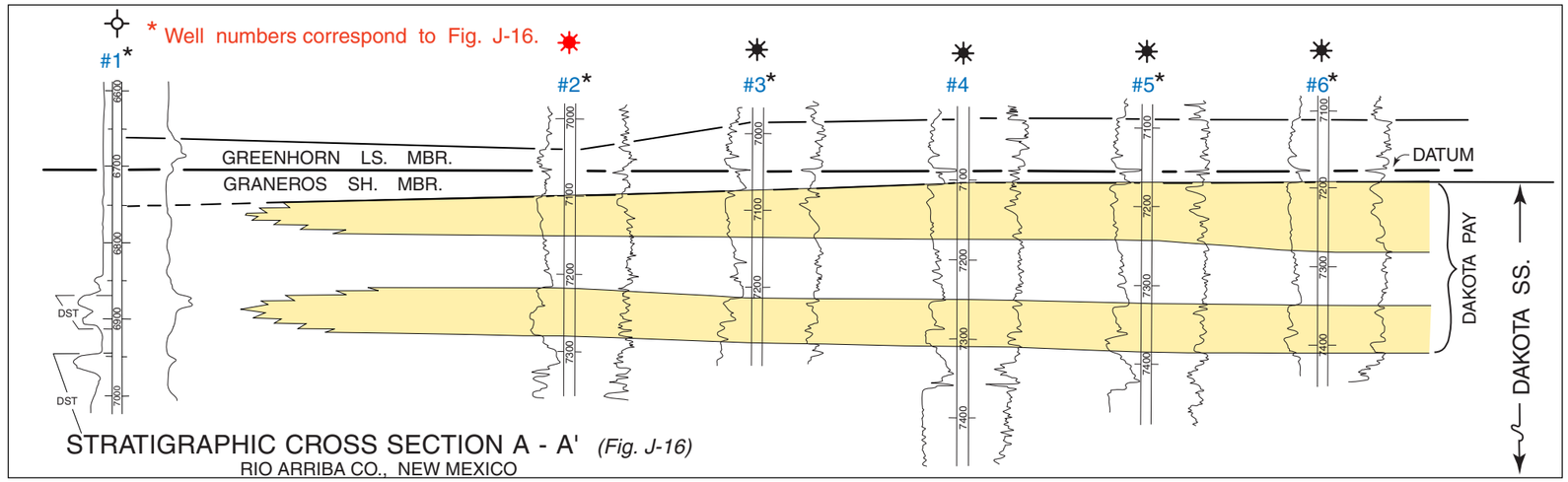

Figure J-17. South Lindrith Gallup-Dakota Field, cross section along A-A' (figure J-16) (from Matheny, 1978, p. 983).

Analog Field
BLANCO TOCITO SOUTH
Figures J-18 and J-19

Location:	T26N, R5-6W, on Reservation
Formation:	Tocito Sandstone Lentil of Mancos Shale
Lithology:	Sandstone
Average Depth:	6,625 feet
Porosity:	15.1%
Permeability:	138 mD
Oil/Gas Column:	30 feet oil, 50 feet gas
Average Net Pay Thickness:	16 feet
Other Information:	Oil is 43 degree API, paraffin based. Gas contains 1,233 Btu/CF with 0.0002% H_2S. Field primary recovery is 12% OIP or 1,680,000 BPO increased by secondary recovery to 40% OIP or 5,600,000 BO.

TOCITO-GALLUP SANDSTONE OIL PLAY
USGS 2207

The Tocito-Gallup Sandstone Oil Play is an oil and associated gas play in lenticular sandstone bodies of the Upper Cretaceous Gal lup Sandstone and Tocito Sandstone Lentil associated with Mancos Shale source rocks lying immediately above an unconformity. The play covers almost the entire area of the province. Most of the pro ducing fields involve stratigraphic traps along a northwest-trending belt near the southern margin of the central part of the San Juan Ba sin. Almost all production has been from the Tocito Sandstone Lentil of the Mancos Shale and the Torrivio Member of the Gallup Sand stone.

Reservoirs: The Tocito Sandstone Lentil of the Mancos Shale is the major oil producing reservoir in the San Juan Basin. The name is ap plied to a number of lenticular sandstone bodies, commonly less than 50 ft thick, that lie on or just above an unconformity and are of unde termined origin. Reservoir porosities in producing fields range from 4 to 20 percent and average about 15 percent. Permeabilities range from 0.5 to 150 mD and are typically 5 - 100 mD. The only signifi cant production from the regressive Gallup Sandstone is from the Torrivio Member, a lenticular fluvial channel sandstone lying above and in some places scouring into the top of the main marine Gallup Sandstone.

Source rocks: Source beds for Gallup oil are the marine Upper Cre taceous Mancos Shale. The Mancos contains 1-3 weight percent or ganic carbon and produces a sweet, low-sulfur, paraffin-base oil that ranges from 38 degrees to 43 degrees API gravity in the Tocito fields and from 24 degrees to 32 degrees API gravity farther to the south in the Hospah and Hospah South fields.

Timing and migration: The upper Mancos Shale of the central part of the San Juan Basin entered the thermal zone of oil generation in the late Eocene and gas generation in the Oligocene. Migration updip to reservoirs in the Tocito Sandstone Lentil and regressive Gallup fol lowed pathways similar to those determined by present structure be cause basin configuration has changed little since that time.

Traps: Almost all Gallup production is from stratigraphic traps at depths between 1,500 and 5,500 ft. Hospah and Hospah South, the largest fields in the regressive Gallup Sandstone, are combination stratigraphic and structural traps. The Tocito sandstone stratigraphic traps are sealed by, encased in, and intertongue with the marine Man cos Shale. Similarly, the fluvial channel Torrivio Member of the Gal lup is encased in and intertongues with finer grained, organic-rich coastal-plain shales.

Exploration status and resource potential: Initial Gallup field dis coveries were made in the mid 1920's; however, the major discoveries were not made until the late 1950's and early 1960's. These were in the deeper Tocito fields, the largest of which, Bisti, covers 37,500 acres and has estimated total ultimate recovery of 51 MMBO. Gallup producing fields are typically 1,000 to 10,000 acres in area and have 15 to 30 ft of pay. About one-third of these fields have an estimated cumulative production exceeding 1 MMBO and 1 BCF of associated gas. All of the larger fields produce from the Tocito Sandstone Lentil of the Mancos Shale and are stratigraphically controlled. South of the zone of sandstone buildups of the Tocito, the regressive Gallup Sand stone produces primarily from the fluvial channel sandstone of the Torrivio Member. The only large fields producing from the Torrivio are the Hospah and Hospah South fields, which have combination traps. Similar, undiscovered traps of small size may be present in the southern half of the basin. The future potential for oil and gas is low to moderate.

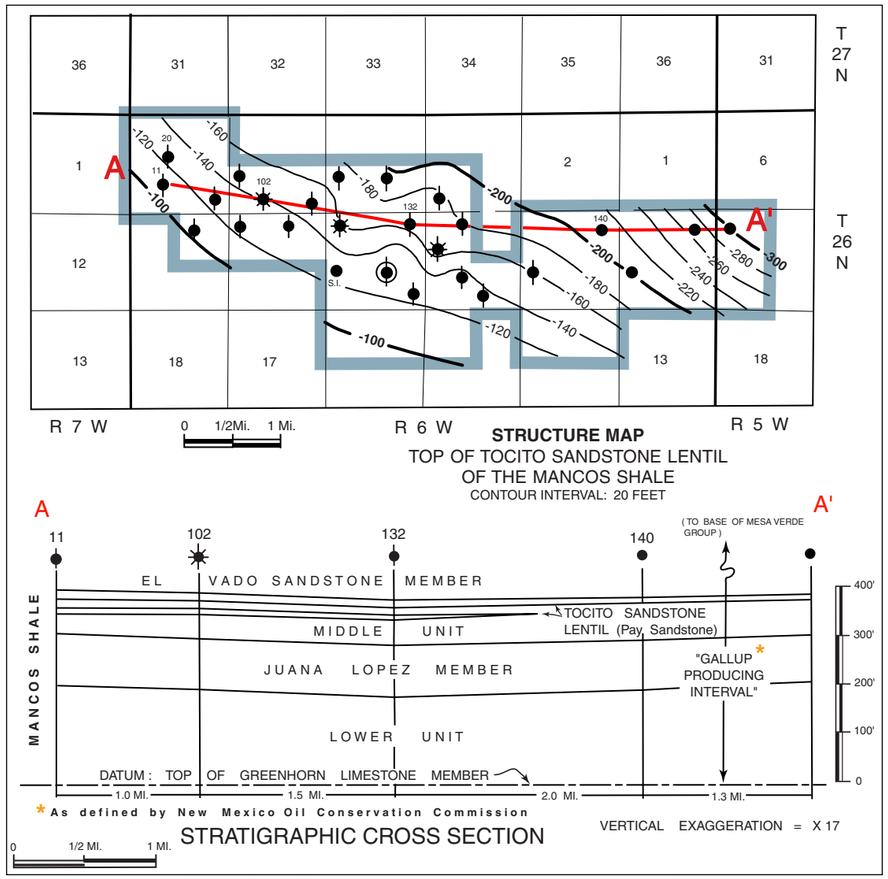

Figure J-18. Blanco Tocito South Field structure map and cross section (from Fassett and Jentgen, 1978, p. 233).

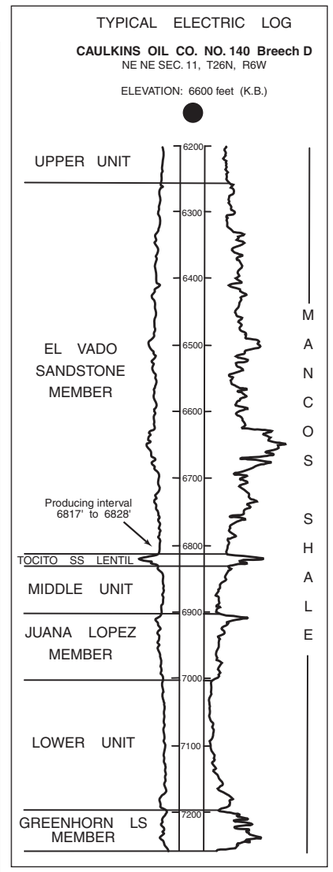

Figure J-19. Bianco Tocito South Field example electric log (from Fassett and Jentgen, 1978, p. 234).